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Silicone Lubricating Grease

T. A. Kauppi — Dow Corning Corporation

A grease, as defined by the dictionary, is a thick oily or buttery preparation, and the term applies to any thick lubricant. Normal technical usage, however, distinguishes between oils and greases in that an oil exhibits mainly viscous flow properties over the whole range of applied force, while a grease has definite resistance to flow in the lower range of applied force. This resistance to flow is usually great enough so that the grease will retain its shape and position against the action of the force of gravity. A grease, or "buttery preparation" can in general be made with any oil or fluid as the vehicle by the proper choice of a thickening agent.

When the silicone fluids first appeared, and while their properties were being evaluated, it became apparent that they should make almost ideal vehicles for lubricating grease. Most discussions of the properties required in an oil for making a lubricant of grease-like consistency emphasize exactly those properties for which the silicone fluids are outstanding. Some of these properties are:

(a) Low change of viscosity with temperature
(b) Low volatility
(c) Resistance to oxidation
(d) Stability at high temperatures
(e) Low freezing point

When all of the above properties are available in a single fluid, it becomes unnecessary to make compromises in the properties of the final grease, such as sacrificing high-temperature stability for the sake of good performance at low temperatures.

The first silicone material having a grease-like consistency found extensive use as a waterproofing and sealing compound in aircraft ignition systems and as an auxiliary dielectric material in radio systems. This Silicone material known as DC 4 Compound is colorless and translucent and can be made in a wide range of consistencies but is usually furnished at a penetrometer of 240-260. It is extremely waterproof and water-repellent and retains its grease-like consistency from −40° to over 400°F.

DC 4 Compound was tried repeatedly and hopefully as a lubricant for ball bearings, and in every case gave very poor results. Wear was extremely high, bleeding occurred, torque was high, and the bearing life was usually in the order of 24 hours or less. DC 4 Compound, however, did find a type of lubricating use as a surface treatment for ignition cable in wiring up the harness. A similar compound, DC 7, has proved to be very effective as a lubricant for the rubber bags used in low-pressure molding. In these applications, water repellency, oxidation resistance and inertness to synthetic rubber are quite important. Similar grease-like materials are used for lubricating glass and ceramic stopcocks and for pressure lubricated valves. A special silicone grease has also been developed for lubricating joints in systems operated at high vacuums. In these uses, thermal stability and chemical resistance are the most important factors, as the actual lubricating requirements are quite mild.

Silicone Bearing Lubricants

The problem of making a good silicone grease for bearing lubrication was complicated by two factors. The first was that any thickening agent used should have about the same order of heat stability as the silicone fluids; the second was that most of the metallic soaps proved to be insoluble in the silicone fluids. However, the problem was finally solved by two different methods and at the present time two types of silicone lubricating greases are being made.

One of these two types of silicone lubricating greases DC 41, is designed for bearings operating at temperatures up to 200°C. and at speeds which are relatively low. The other type of silicone lubricating grease is produced in two formulations, DC 33 and DC 44. DC 33 is designed for high speed bearings operating at very low temperatures

TABLE I

Percentage of Weight Lost After 40 Hours at 175°C. (347°F.)

High Temperature Petroleum Greases			Dow Corning Silicone Greases		
A	B	C	DC 33	DC 41	DC 44
58.3%	39.3%	34.8%	4.6%	4.2%	3.3%

After 40 hours exposure at 175°C., a crust had formed over the surface of the three petroleum greases. The silicone greases were still soft and serviceable.

TABLE II

SPECIFICATIONS FOR DOW CORNING SILICONE GREASES

	DC 33	DC 41	DC 44
WORKED PENETROMETER (ASTM-D 217-44T)	280-330	295-305	240-260
FLASH POINT (ASTM-D 92-33)	525°F.	535°F.	550°F.
DROPPING POINT (ASTM-D 566-42)	390°F.	390°F.	390°F.
not less than	200°C.	200°C.	200°C.
BLEEDING (ANG-3A Specification)			
16 hrs. at 110°C.—less than	2%	4%	2%

The properties of these three Silicone greases will be discussed in greater detail in the following pages, and the results of some of the tests conducted to determine their lubricating life will be described.

but it also has good lubricating life at elevated temperatures. DC 44 is designed for bearings operating at elevated temperatures but at speeds up to 10,000 R.P.M.

PROPERTIES AND SPECIFICATIONS

An indication of the low volatility of these silicone greases is contained in Table I.

These three silicone greases are manufactured to conform to the specifications in Table II.

SILICONE GREASE DC 41

In this silicone grease, a very finely divided carbon black is used as the thickening agent for a silicone fluid of good lubricity. It was the first which showed promise in the lubrication of ball bearings. In one series of tests, six no. 212 ball bearings were mounted on a shaft in an enclosure which could be heated to any desired temperature. This testing device is shown with the oven lid open in Figure I. Each bearing was spring-loaded with 150 lbs. radial load, and the shaft rotated at 1750 R.P.M. by a 1 H.P. motor. Failure of the bearings was determined by several methods.

(1) Decrease in the time required for the rotating shaft to coast to a stop when the motor is shut off.

(2) Observation of any abnormal temperature rise of an individual bearing by means of a thermocouple placed in each bearing housing.

(3) Observation of any sudden increase in power required to drive the test set as indicated on a watt meter.

These three indications of bearing failure have, in general, appeared simultaneously and seem to coincide with the first appearance of unusual noise from the test set.

This test set was first used to evaluate the life of DC 41 grease at 150°C. (302°F.) and an average bearing life of about 1300 hours was established. At 125°C. (257°F.) the bearing life was 6000 hours. These figures are about eight times the values that were observed with the best petroleum greases.

However, when these results were checked on the bearings of electric motors, it was found that the results were much less favorable. The principal difference between the two test methods, it was found, was that in the six-bearing tester described above the ball bearings had bronze retainer rings and in the electric motors, the bearings had steel retainers. The laboratory test set could be run until an actual grease failure was indicated by hardening of the grease, while in the bearings with steel retainers the failures were due to wear or breakage of the retainers.

The conclusion to be drawn from this test is that DC 41 is a relatively poor lubricant for hardened steel balls against a soft steel retainer, while it is a good lubricant for steel balls rubbing on a bronze retainer. This agrees well with wear-testing results reported previously [1] on silicone fluids. Despite this behavior, however, DC 41 has been used in bearings with steel retainers.

(1) Silicones as Lubricants by T. A. Kauppi and W. W. Pedersen. Technical Section, National Petroleum News. December 5, 1945. S. A. E. Journal March, 1946.

FIGURE 1—SILICONE LUBRICATING GREASE DOW CORNING PHOTOGRAPH

In the test device shown at center, six No. 212 ball bearings are mounted on a shaft, and spring-loaded with 150 pounds radial load. Shaft and bearings are enclosed in an oven which may be heated electrically to any desired temperature. The shaft is rotated at 1750 R.P.M. Laboratory technician is checking coasting time on single bearing tester. In this set a No. 212 bearing with bronze retainer ring is operated in an electrically heated cast iron housing. Shaft is rotated at 1750 R.P.M.

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ith considerable success, especially in high-emperature applications. It will function as grease at temperatures of 200°C. and bove, and in some specialized applications, uch as in the pumping of very hot liquids in bearings which must be located in igh-temperature ovens, DC 41 has definite alue. If bearings with bronze retainers can e obtained they will give several times the fe obtainable with ordinary bearings.

SILICONE GREASE DC 44

Several tests made in high-speed bearings ith DC 41 showed that it was not at all atisfactory. At 10,000 R.P.M. and 150°C. failed within 24 hours, and in addition roduced excessive friction and temperature se in the bearing. Testing of various grease ompositions eventually resulted in DC 44, hich is a silicone fluid thickened with heat table metallic soaps. DC 44 has now been ested quite extensively at both 1750 and 0,000 R.P.M. and at bearing temperatures etween 115°C. (239°F.) and 200°C. 392°F.). The tests have been of three dis-nct kinds, as described below.

I. Single-Bearing 1750 R.P.M. Tester.

In this test a No. 212 bearing with a ronze retainer ring is operated in an elec-rically heated cast iron housing (See Fig-re I.). Grease failure is determined by measuring both hot and cold coasting times and by observation of the appearance of the grease at intervals. As is shown in Table III grease failure occurred after 2600 hours at 150°C., or after 450 hours at 200°C. Tests at lower temperatures are now being conducted, but it obviously will take many months to reach a definite result.

TABLE III
LIFE TEST ON DC 44 GREASE
Test Method and Lubrication Life in Hours

Bearing Temperature °C.	Bearing Temperature °F.	I. 1750 R.P.M. Tester	II. 1750 R.P.M. Electric Motor	III. 10,000 R.P.M. Tester
115	239		>3500	
125	257		>2500	>2800
150	302	2600		2200
200	392	450		

II. Bearings in 1750 R.P.M. Electric Motors.

Grease tests are relatively easy to run in laboratory bearing test sets, but it is always debatable whether the results will compare with those obtained in actual use. Bearing loadings, vibration conditions and other mechanical factors are hard to duplicate in the laboratory, and actual thermal gradients inside the bearing of an electric motor are quite different from those produced in laboratory tests. In the normal type of induction motor, operated at high temperature, the heat flow is outward through the motor shaft, and the outer race of the bearing therefore is cooler than the inner race. In a laboratory bearing, such as described in method I, the temperature gradients are reversed, in that the heat flows from the hot housing through the bearing to a cooler shaft. The inner race, then, is cooler than the outer race. In the case of a test bearing operated in an oven, the thermal gradients

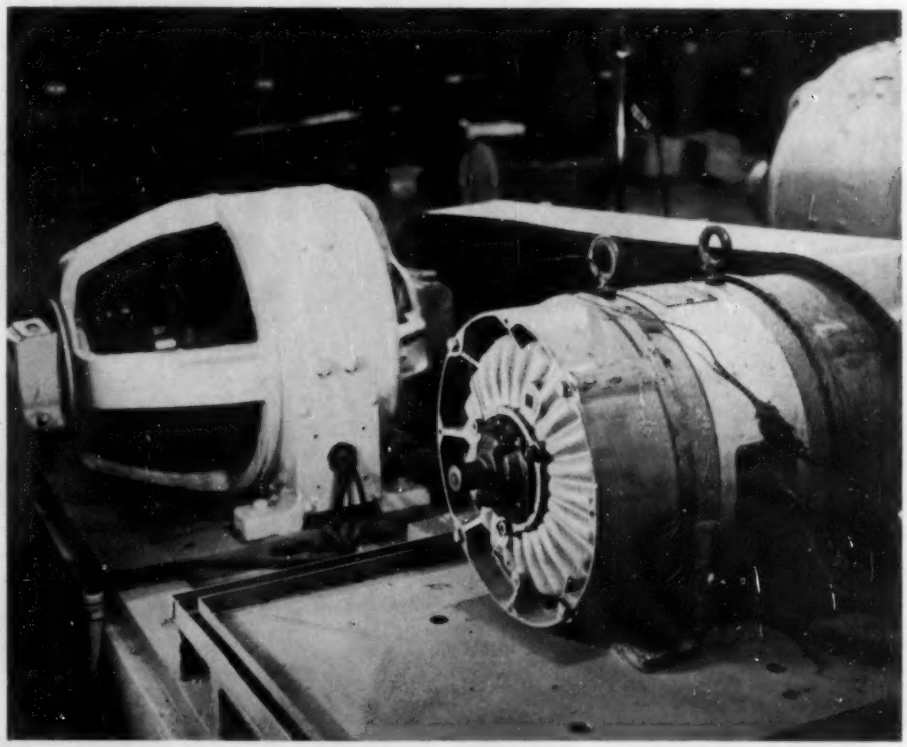

FIGURE 2—SILICONE LUBRICATING GREASE DOW CORNING PHOTOGRAPH

Silicone insulated 7½ H.P., 1750 R.P.M., 440 volt induction motor is belt connected to a generator and loaded so that bearings operate at temperatures up to 150°C. in testing Silicone greases.

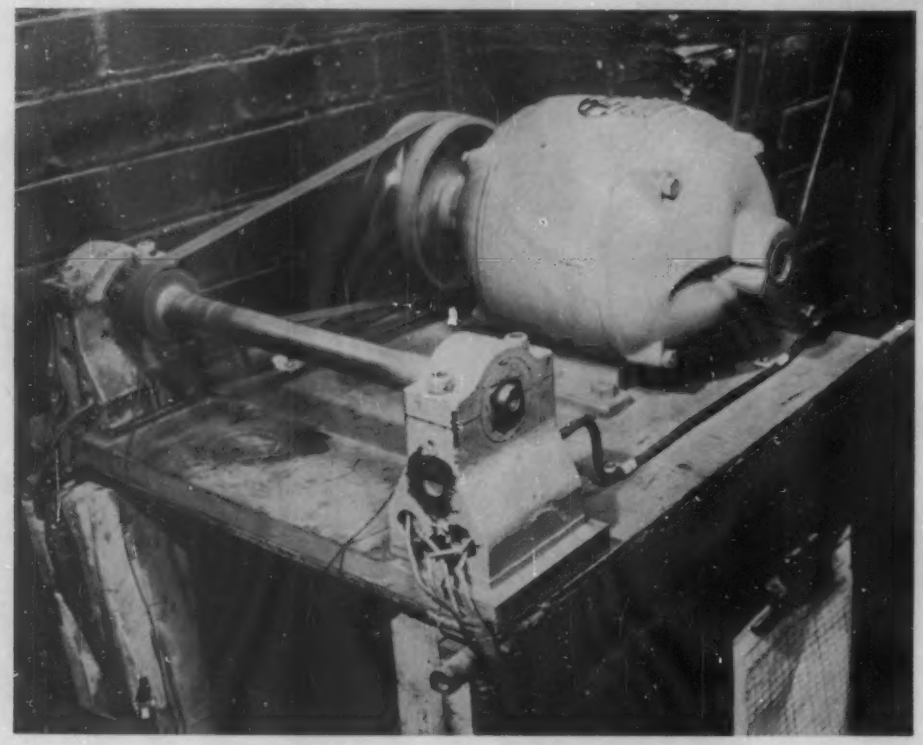

FIGURE 3—SILICONE LUBRICATING GREASE DOW CORNING PHOTOGRAPH

Grease testing device consists in two standard No. 204 Bearings mounted in electrically heated cast iron blocks. The bearings support a shaft, belt driven at 10,000 R.P.M. Changes in torque are measured by temperature rise of the bearings and changes in hot and cold coasting time are used as indications of bearing failure.

will be quite small with only the small amount of heat generated in the bearing flowing out through both the inner and outer race.

The above considerations led to tests of DC 44 in electric motors. Bearing temperatures are produced by actually loading the motor to the desired extent with a belt-driven generator. This test set-up is shown in Figure 2. The motors used are 7½ H.P., 1750 R.P.M., 440 volt induction motors, and they are insulated with silicone varnishes to permit operation of the bearings at temperatures up to 150°C. Motor winding temperatures may go as high as 275°C.

Column II in Table III shows that the two tests, at 115°C. and 125°C., are still in operation after 3500 and 2500 hours. Motor coasting times, which are taken with the bearings both hot and cold, and the bearing temperature rise obtained with the motor operating under no load, indicate that little if any change has occurred in the bearings or in the DC 44 Grease.

III. 10,000 R.P.M. Tester.

This tester is shown in Figure 3 and consists of two standard No. 204 Bearings mounted in cast iron blocks which are electrically heated. The bearings support a shaft which is belt-driven at 10,000 R.P.M. Changes in torque are measured by temperature rise of the bearings and changes in hot or cold coasting time are used as indications of bearing failure. As shown in Table III, failure was obtained at 2200 hours at 150°C., while another bearing was still operating after 2800 hours at 125°C. Several high temperature petroleum greases have been tried in this tester and failure has occurred in the range of 50 to 200 hours.

These results indicate that DC 44 has about ten times the life of a good petroleum grease at high temperature and high speed. This agrees quite well with the results shown in Column I of Table III, and indicates that in bearings with steel retainers DC 44 has as long a service life as it has in bronze retainers.

During the operation of the 10,000 R.P.M. tester with DC 44, the bearing temperature on two separate occasions was inadvertently allowed to go above 200°C. In one case, it went to 225°C. for one hour, and in the other to 240°C. for 15 minutes. This occurred in about the middle of the test run, and did not seem to affect the grease appreciably. It is likely, however, that the grease life was considerably shortened by these extreme temperatures, and it would be surprising if the metals in the bearing were not harmed by this treatment.

SILICONE GREASE DC 33

In the first portion of this paper, it was pointed out that if all the desirable properties are obtainable in one fluid, it becomes unnecessary to make special greases for different operating conditions. However, even with silicone fluids as grease vehicles, it has not yet been possible to make a grease that has the extreme high temperature performance of DC 44 and an extremely low freezing point. DC 44 will operate well at a temperature of −40°F., but begins to stiffen at −50°F. Some applications, mostly military, require performance at even lower temperatures, and this can be obtained with DC 33.

DC 33 is a soap-type grease similar to DC 44, but begins to get stiff at temperatures in the order of −70 to −80°F. Bearing tests have shown that its life at high temperature is about half that of DC 44, so that it is still four to five times as heat-stable as the best organic high temperature greases.

DISCUSSION

The test results described above show that silicone lubricating greases can be used to obtain operation of ball bearings at temperatures far above those considered practical with petroleum greases. In addition, a silicone lubricating grease can be made with excellent low temperature behavior and with high temperature stability considerably better than that of the most stable petroleum greases.

The greatest significance of the test results, however, is that DC 44 offers the possibility of a completely stable grease for the permanent lubrication of ball bearings. Lack of bleeding, extremely low volatility, and absence of gumming tendencies even at elevated temperatures, indicate its suitability as the lubricant for bearings which must operate for years without attention or relubrication.

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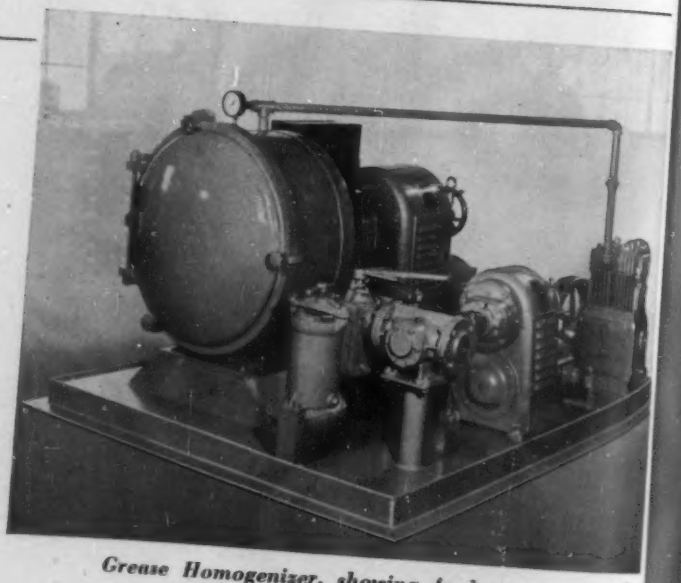

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